

atoms double-linked, others two pair, and another as many as three pair. On these three suppositions its refraction equivalent would be 73.0, 75.2, and 77.4 respectively. Now the various isomeric terpenes have a refraction equivalent of about 72.9, leading to the belief that only one pair of carbon atoms is in that condition. This conclusion is enforced by the specific dispersion, which averages 0.0299. From the analogy of other compounds containing ten atoms of carbon and which are of known constitution, about this amount of dispersion might be expected to occur in a $C_{10}H_{16}$ having one pair of carbon atoms double-linked.

I do not know how far chemists may be disposed to accept these optical properties as the arbiter between rival theories of constitution; but their value as helps will not be denied.

With reference to this mode of experimenting, it should be borne in mind that a very small quantity of a substance suffices for the purpose of observation; and whereas chemical processes use up material, the refraction of a liquid can be taken with no other loss than the small amount which unavoidably clings to the vessels employed. This even may be recovered if it is worth the trouble.

A table of the approximate refraction equivalents of forty-six of the elements was drawn up for my paper in the *Phil. Trans.* of 1869. Many of these have since been re-determined, either by myself or other observers; and a new edition of the table was prepared for the Montreal Meeting of the British Association, and appears in the *American Journal of Science* of January 1885. Carbon, oxygen, nitrogen, sulphur, phosphorus, iron, chromium, silicon, and doubtless other elements have two or three different values; and the special circumstances under which these different effects upon the rays of light occur offers a most promising field for any future investigator.

J. H. GLADSTONE

THE RAINFALL OF THE BRITISH ISLANDS¹

CLIMATE may be defined as that peculiar state of the atmosphere in regard to heat, moisture, and rainfall which prevails in any particular place, together with its meteorological conditions generally, in so far as these influence animal and vegetable life. The diversified characters which climate displays may be referred chiefly to the combined operation of these four different causes, viz., distance from the equator, height above the sea, distance from the sea, and prevailing winds.

The greatest differences, however, in the local climates of places situated at no great distance from each other arise from differences in the rainfall. The arid plains of the North-Western Provinces of India as compared with the fertile higher slopes of the Himalayas contiguous to them, and the widely contrasted climates of the western and eastern slopes of Scandinavia respectively, may be cited as illustrations. In the British Islands there are perhaps no stronger contrasts of climate than those pre-ented by Skye and the Laigh of Moray. The mean temperature of these two regions in no month of the year differ so much as two degrees, and for several of the months they are nearly identical. But the rainfall of Skye rises towards, and in many places exceeds, 100 inches annually, whereas over the Laigh of Moray it is only about 26 inches. Now it is this difference in the rainfall, with the clear skies and strong sunshine that accompany it, which on the one hand renders the south shores of the Moray Firth one of the earliest and finest grain-producing districts of Scotland; and, on the other, renders the island of Skye quite unsuitable for the remunerative cultivation of cereal crops. It is this aspect of the rainfall which gives it so paramount a place in the climatology of a country.

Of all meteorological data, the rainfall is the most difficult to represent cartographically; and there is no other way to arrive at even a tolerable approximation to the average rainfall of a district than by numerous rain-observing stations well distributed over its surface. Hence in this inquiry all available statistics of the rainfall for the period of years selected have been used,—the number of stations being 1080 in England and Wales, 547 in Scotland, and 213 in Ireland—in all, 1840 stations. Notwithstanding this comparatively large number of rain-gauges, very extensive districts remain wholly, or all but wholly, unrepresented.

The period selected for the investigation is the twenty-four

years ending 1883, and the principal sources from which the information has been obtained are the returns published by the Meteorological Societies of England and Scotland and by Mr. Symons. For the method of discussing the results we refer to the recently published Part of the *Transactions* of the Scottish Meteorological Society, pp. 131-33. It may be here enough to say that the whole of the averages have been calculated for, or reduced to, the same term of twenty-four years beginning with 1860 and ending with 1883.

The 1840 averages were then transferred to large maps of England, Scotland, and Ireland, and from the results thus shown the British Islands were shaded into six divisions, these shadings showing the districts where the mean annual rainfall

1st	does not amount to	25 inches
2nd	is from	25 to 30 "
3rd	"	30 " 40 "
4th	"	40 " 60 "
5th	"	60 " 80 " and
6th	above	80 inches.

On the map exhibited on the wall these divisions are shown by three tints of blue and three of red,—the blue showing a rainfall exceeding forty inches annually, and the deepest tinted blue the regions of largest rainfall; and the red a rainfall less than 40 inches, the lightest tint marking off those parts of England where the rainfall is least, or where it is less than 25 inches annually.

The regions of heaviest rainfall, marked off by 80 inches annually, or upwards, are these four:—

- (1) The greater part of Skye, and a large portion of the mainland to the south-east, as far as Luss.
- (2) The greater part of the Lake District.
- (3) A longish strip including the more mountainous portion of North Wales, and
- (4) The mountainous district of the south-east of Wales.

The rainfall is also heavy on Dartmoor, and certain portions of the west of Ireland; but in these parts it does not appear quite to reach 80 inches.

The West Highlands present the most extensive region of heaviest rainfall in the British Islands. The mountain-masses along whose slopes and plateaus the rainfall is precipitated, offer a practically unbroken face of Highlands directly in the course of the rain-bringing winds from the Atlantic. Particular attention is drawn to the circumstance that these mountain-masses present many lochs and valleys directly in the course of these winds, up which therefore the winds are borne, and these cooling as they ascend pour down the deluges of rain which deeply trench the sides of the mountains in the lines of their water-courses.

This region of heaviest rainfall lies so far to the north of Ireland that the rainfall is not lessened by a previous partial drying of the Atlantic winds in their passage thither. To southward, however, it is quite different. Over the whole of the extensive tract of Great Britain from Luss to the Lake District there is not a single rain-gauge whose annual average reaches 80 inches, even although a number of rain-gauges have been planted in the higher districts, and in positions likely to furnish approximately the maximum rainfall of these districts. The diminished rainfall is no doubt due to the partial drying of the Atlantic winds in their passage across Ireland before they reach Southern Scotland.

St. George's Channel and the Irish Sea open a free passage to the south-westerly winds, here diverted into a more southerly course, to the north of England and to Wales, and accordingly where the mountain masses of the Lake District and of North and South Wales oppose their course the rainfall over large portions of these high districts exceeds 80 inches.

The maximum falls in these four districts respectively are 185.96 inches at The Styx, in the Lake District; 128.50 inches at Glencroe, Argyllshire; 116.90 inches at Beddgelert, North Wales; and 96.18 inches at Ty-Draw-Treherbert, South Wales.

The largest region of 60 to 80 inches rainfall is in the West Highlands, surrounding the region of still larger rainfall of 80 inches and upwards, and it extends from the Crinan Canal to beyond Loch Assynt in Sutherland. Then follow the hills to the north of Galloway, the hills to the north and east of Dumfriesshire, large portions of the Lake District, of North and South Wales, of West Galway, the mountainous districts of Kerry, and Dartmoor in Devonshire.

¹ An Address delivered to the Philosophical Society of Glasgow on December 16, 1885, at the request of the Council, by Alexander Buchan.

An annual rainfall of 40 to 60 inches covers extensive tracts of the British Islands; a rainfall of at least 40 inches characterising the climates of about a fourth part of the surface of England, of about the half of Ireland, and considerably more than the half of Scotland, the latter taken as a whole being by far the rainiest of the three divisions of the United Kingdom. It is to be noted that nowhere along the east coast of Great Britain, or for some considerable distance inland, does the average rainfall anywhere reach 40 inches. In the east of Ireland, on the contrary, the rainfall exceeds 40 inches in Wicklow, the south of Down, and the middle districts of Antrim, which is probably due to the south-westerly winds being diverted into a more southerly direction in their passage through the Irish Sea.

Over the whole of the west of Great Britain the rainfall exceeds 40 inches annually, except from St. Bees' Head to Dumfries, and from Holyhead to Lancaster, these districts being largely protected from the rain-bringing winds by the Cumberland and the Welsh mountains respectively. It may also be stated that the rainfall of the Orkney and the Shetland Islands falls short of 40 inches, whereas in the Hebrides it exceeds that amount.

The shadings of blue on the map show in a striking manner the extension eastwards of the areas of the 40 inches and upwards annual rainfall by the mountains of Sutherland, the Grampians, the Cheviots, the Pennine Range, and the hilly ground of the south-western counties of England.

On the other hand, the breakdown at various intervals of the mountainous or hilly plateau which may be regarded as extending along the west of Great Britain from Cape Wrath to the Land's End has an equally striking influence on the distribution of the rainfall, and as regards man's material interests is even more important. Thus the opening of the Bristol Channel, between Wales and the Cornish Peninsula, is the avenue through which is spread a more generous rainfall over a large portion of Central England than would otherwise have been the case. Through the breakdown of the plateau between the Pennine Range and North Wales another large portion of England, extending from Cheshire round by Derbyshire, and thence northward through Yorkshire, has its rainfall also very materially increased.

But the most remarkable of these breakdowns is the great lowering of the water-parting between the Firths of Forth and Clyde. Through the opening thus formed the south-westerly winds pass freely, and overspread Dumbartonshire, Stirlingshire, and the whole of Western Perthshire, precipitating over these regions a rainfall truly western as regards its copiousness and the direction of the winds with which it falls; and through the same breakdown there is extended, even eastward through Kinross-shire, a rainfall of fully 40 inches—an amount which occurs nowhere else over comparatively level plains so far to the east of the water-parting between eastern and western districts.

Of the greatest importance is it to note the rainfall of Clydesdale, lying to the south of this breakdown. The amounts are, in inches, 29·98 at Bothwell Castle, 30·54 at Dalziel House, 31·66 at Auchinraith, and 32·37 at Murdostoun. Now it is simply the *southerly* element of the rain-bringing winds which makes the rainfall of the Hamilton district of Clydesdale so essentially different, both as respects its amount and the times of its occurrence, from that of the Clyde below Glasgow. It may be noticed here that when the rainfall of the west is in excess of the average the rainfall of West Perthshire is also in excess; and on the other hand, when there is an excessive rainfall over the Hamilton district, it generally occurs that the rainfall of eastern districts is also in excess. The peculiarity of the rainfall of Glasgow consists in this—that it lies midway between those districts which are so differently circumstanced.

The valleys of the counties of Kirkcubright with Dumfries and the intervening ridges lie athwart the course of the rain-bringing winds, and show the inevitable result of a rainfall successively diminishing on advancing eastward. But on arriving in Eskdale, the most easterly of these valleys, we meet with a rainfall considerably in excess of that of any of the valleys to westward at the same elevations. The larger rainfall of Eskdale is due to its lying more in the line of the Solway, and having immediately to eastward a high mountainous region which the south-westerly winds must cross in their passage to eastward.

The distribution of the rainfall over this hilly region and over the valleys on each side of it is instructive. Thus at Kirkconnel Hall, near Ecclefechan, it is, in inches, 39·64; Canonbie, 49·72; Carlesgill, 58·00; Eskdalemuir, 63·30; Tudhope (on the ridge,

1961 feet high), 76·43; and on the east of the watershed at Teviothead, 54·86; Borthwickbrae, 44·36; Hawick, 33·55; and thence continues diminishing in descending the valley to 26·50 at Springwood Park, near Kelso. The reason why the rainfall of this region is thus distributed is that the air on the windward side of the ridge being suddenly raised to a greater height in crossing the range its temperature is continually reduced by mere expansion, and copious precipitation follows; whereas on the leeward side, as the air descends to lower levels, its pressure (or density) being increased, and its temperature also thereby increased, it gradually becomes drier, and accordingly the rainfall diminishes rapidly with the descent of the aerial current to the lower plains. A similar distribution of the rainfall is seen in crossing the Downs from Brighton to London, and over all other regions similarly situated.

It is the rapid increase of the temperature and drying of the air as the wind passes from high and wide plateaus into lower levels which determines the areas of least rainfall of the British Islands. Accordingly the smallest average annual rainfall, varying from about 22½ to 25 inches, occurs in England, and overspreads a large portion of the south-eastern counties extending from the Humber to the estuary of the Thames, exclusive of the higher grounds of Lincoln and Norfolk, where the rainfall rises above 25 inches. In every other part of the British Islands the rainfall is above 25 inches. The influence of the higher grounds of Norfolk and Lincoln in swelling the rainfall, most probably by increased falls with easterly winds, is very striking. Similarly the rainfall of the Yorkshire Wolds is in excess of surrounding districts. Between the valley of the Thames and the Humber the rainfall nowhere exceeds 30 inches, except near the Chiltern Hills.

It will be observed that the northern limit of the region marking off a rainfall under 25 inches annually is at the Humber, or near where Great Britain suddenly shrinks in breadth. It is, however, probable that the larger rainfall of the eastern part of Yorkshire, as compared with what obtains further south, may also, in part, be occasioned by causes analogous to those which give Western Perthshire its large rainfall.

In Scotland no rain-gauge gives an annual average under 25 inches. In three districts, however, the averages are only slightly in excess of 25 inches, and less than 27 inches: these districts being (1) Lower Tweeddale from about Coldstream to Jedburgh; (2) the low-lying parts of East Lothian; (3) the shores of the Moray Firth from the mouth of the Spey round to Tain. It will be seen that these districts are not only well protected by extensive highlands from the rains of the south-westerly winds, but also from the, in many cases, torrential downpours of south-easterly winds. It is this double protection which gives the driest of its climates to these parts of Scotland.

In Ireland, on the contrary, only a small district round Dublin shows a rainfall less than 30 inches, this district being well protected by the Wicklow mountains from the rain-bringing winds; and as in that island there is no continuous mountain-mass stretching north and south there is no such great difference of rainfall and temperature shown between the eastern and western climates of Ireland as in the case of Scotland and England.

The narrowness of the strip round the east of Scotland where the rainfall does not exceed 30 inches a year is an interesting feature, of which the rain-maps constructed for individual months suggest the explanation. Of the rainfall of eastern districts the larger proportion is due to easterly winds, and by much the larger portion of these falls usually takes place neither on the low-lying coasts, nor at any great distance inland, but in the intermediate region at heights from about 250 feet and upwards. The falls are also very heavy in low-lying valleys that open out so as to face these rain-bringing easterly winds. Of these rains the weather of October 1880 afforded an excellent illustration. The rains of that month fell with strong north-easterly winds, and the foreshores, looking to the north-east, of the Firth of Forth, the Moray Firth, and the Pentland Firth, had a monthly rainfall above the average, being in some places more than double the average; whereas over the rest of Scotland the rainfall was under the average, being over very extensive breadths from 70 to 98 per cent. less than the mean rainfall for October.

One of the most marked features of the climates of the south of England, to which many of our invalids are sent, is due to the influence of the Downs on the rainfall. Over the whole of the somewhat broad region occupied by the Downs the rainfall exceeds 30 inches, rising near Petersfield to 40 inches. Along the south coast, and for a varying distance inland as determined by

the physical configuration, the average is less than 30 inches from Dover westward as far as the east shores of the Isle of Wight. On proceeding still farther westward, the annual rainfall slowly but steadily rises, till on rounding Prawle Point in Devonshire it begins to exceed 40 inches, and with this increase of the rainfall there is a still more striking increase of temperature in the winter months.

The whole of the results arrived at in this inquiry show conclusively that the key to the distribution of the rainfall of the British Islands is the direction of the rain-bringing winds in their relation to the physical configuration of the surface.

Looked at broadly, there are four very distinct causes of rain, viz. (1) the moist south-westerly winds; (2) rains, often very heavy rains, from the east, extending but a little way inland; (3) the annual fall of temperature from August to January; and (4) those peculiar influences that have their fullest development in the thunderstorms of summer over low-lying extensive plains.

The rainfall of the British Islands has been examined with reference to its seasonal distribution in relation to the physical configuration of the surface. The mean amount of each place for the past twenty years has been calculated for the twelve months, these being reduced to thirty days each. The mean of these twelve months being taken, the mean monthly rainfall of the year was then ascertained, and with this latter mean each monthly mean was compared, and its excess, or defect, entered in percentages on twelve maps.

The moist south-westerly winds acquire their maximum annual predominance in December and January, and as these winds come loaded with the vapour of the Atlantic the rainfall rises above its monthly mean over nearly the whole of Scotland. Two patches, however, are to a great extent exempt, the one being the districts lying on the lee side of the greatest stretch of mountainous land, viz. to the north-east of the Grampians and to the east of the Moffat and Lead Hills. Similarly, in England, during these months, the rainfall is considerably above the average over the whole of the dry districts extending from the Tweed southwards, and bounded on the west by the water-partings of the Mersey and the Severn, and on the south by the Thames, including the northern slopes of Kent.

During the great annual fall of temperature from August to January the greatest excess over the mean monthly rainfall occurs in September and October, when the fall of temperature is most rapid, south-westerly winds very prevalent, and heavy rains with easterly winds, chiefly the easterly winds of cyclones, of most frequent occurrence. In these months the rainfall reaches the annual maximum over large districts in the east of Scotland, and over all but the whole of England.

In northern and extreme western districts nearly all thunderstorms occur during the winter months, whereas few occur in eastern and central districts at this season; but nearly all occur in the summer months—a remark which applies with greatest force to the more extensive level, or comparatively level, portions of the country. Now, from the frequent occurrence of the thunderstorms and thunder-showers, the annual rainfall of these districts approaches to, and in not a few cases reaches, the annual maximum in the summer months. The local excess begins to show in June, and is extended in July much more decidedly over the agricultural districts of England and Scotland that are best suited for the ripening of wheat and barley. In August there is shown a still further development and extension of the summer rains over these and adjoining districts. It is to be noted, however, that during this time the rainfall remains under the average over the extreme south-western, southern, and south-eastern districts of England. In these characteristics of the summer rainfall these important agricultural centres resemble the climates of Central Europe, where the rainfall rises to the maximum during the summer months.

The following are the annual amounts of the rainfall, in inches, in certain districts and along certain lines radiating from Glasgow:—Glasgow 40·20, Bresley Hill 37·33, Bothwell Castle 29·98, Dalziel House 30·50, Lanark 35·66, Wiston 45·33; Queen Park 36·24, Newton Mearns 52·63, Black Loch 57·60; Paisley 45·37, Castle Semple 52·10, Blair 53·62, Ardrossan 41·03; Kilbarchan 57·28, Kilmacolm 57·28, Greenock 64·25, Overton 71·45; New Kilpatrick 48·05, Dumbarton 48·25, Cameron House 62·95, Luss 80·45, Firkin 96·05, and Ardlui 115·46. These figures show in a striking manner the extraordinary variations of climates there are in the immediate neighbourhood, or within easy reach, of Glasgow. Quite recently an inquiry was

set on foot in Berlin, where numerous rain-gauges were planted with the view of arriving at some clear understanding as to the amount of observational information required in order to state definitely what the actual rainfall of a district is. Might I suggest to the Mathematical and Physical Section of the Philosophical Society that a similar investigation be taken in hand, and forty or more rain-gauges be added to those already in use. In a few years not only would they be able to answer the question proposed by the Berlin meteorologists, but in answering it they would state with satisfactory precision the character and limits of the various local climates which differ so widely from each other in the neighbourhood of Glasgow.

THE AUSTRALIAN MUSEUM, SYDNEY¹

(1) THE Museum has been, during the year 1884, as in previous years, open to the public daily, except on Mondays, when it is necessarily closed for the purpose of cleaning. The largest attendance on any one day was on December 26, when 1643 persons were registered at the doorway. The greatest Sunday attendance was 1315, on April 13. The average daily number of visitors throughout the year was 262 on week-days and 853 on Sundays. The total for the year is 126,040.

(2) The collections are still being increased by means of purchases, exchanges, collecting expeditions, and donations. A list of these additions, under their separate heads, will be found in Appendices V., VI., VII., VIII. Among these may be specially mentioned several pairs of large antelopes from South Africa, a full-grown orang-outang of the larger species (*Simia satyrus*), and several of the smaller species (*S. morio*): a fine specimen of the Chimpanzee (*Troglodytes niger*); two whales, one from Kiama (*Physeter macrocephalus*), and one from the coast of England, belonging to the extremely rare species known as Rudolf's Whale (*Balenoptera borealis*); casts of gigantic fossil remains from the British Museum, including *Elephas ganesa*, *Mastodon andium*, *Toxodon platensis*, *Sivatherium giganteum*, *Megalanion prisca*, &c.; and large and important ethnological collections.

(3) Great alterations and improvements have been effected by the erection of additional wall-cases, constructed upon the best principles and at considerable cost, for the reception of large collections of skeletons and Australian fossil remains; and for groups of Birds of Paradise, and other exhibits of great interest from New Guinea and elsewhere. Additional cases and cabinets have been provided for the mineral collections, and others are in course of construction for similar purposes.

(4) Want of sufficient space in the present building is still felt as a serious drawback to the usefulness of the Museum. The Trustees nevertheless gladly express their obligation to the Government for the provision now made for further accommodation. An additional shed has been erected, which is used as a store for timber and other material. A large iron workshop has also been provided, and another of similar dimensions is in course of erection. These are to be used for the storage of spirits and bottles, and for workrooms in connection with spirit specimens.

(5) Catalogues, not only of the various collections in the Museum, but also of all branches of Australian Zoology, are still in course of preparation; but no new publications have been issued during the past year.

(6) Mr. Ramsay's visit to Europe in connection with the International Fisheries Exhibition enabled him to examine various Museums, Zoological Stations, and Aquaria, and has been productive of much advantage to this Museum. A report, with particulars of his proceedings and details of his arrangements for purchase and exchange of specimens, will be found in Appendix XI.

(7) The exhibits which are sent to the Calcutta Exhibition have been presented by the Trustees to the Government of India.

(8) The Teaching Collection, consisting of skeletons, models, and specimens illustrative of comparative anatomy and natural history, which for some years past occupied the north room in the upper floor of the Museum, has been transferred to the University. This collection was specially prepared for teaching purposes, and, as most of the specimens were already represented in the Museum, and it occupied space which could be better used for the display of other objects of interest, the

¹ Report of the Trustees for 1884.